Reservoir Optimization (and the Mississippi Headwaters)

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Outline

- Use of Optimization and Simulation
- Mississippi Headwaters ROPE Study
- Articulating Objectives to an Optimization Model
  - use of detailed models
- Penalty curve units
  - how to work with differing units
- Working in ResPRM
- *Example of Penalty Curve generation*

Two Approaches to Modeling

- The ROPE study uses a simulation model and an optimization model
  - A simulation model makes decisions that follow operating rules specified by the user
  - An optimization model makes decisions by maximizing the benefit achieved by various objectives “articulated” by the users

    HEC is uses the Prescriptive Reservoir Model (PRM) to perform optimization analysis

Tasks of the 2 Approaches

- The task of a simulation model is to answer "what if" questions
  - The model "operates" the water system for an historical period with various sets of proposed operating rules
- The tasks of an optimization model are to:
  - evaluate and quantify the tradeoffs between various objectives, and
  - seek operations that achieve a desired balance between those objectives

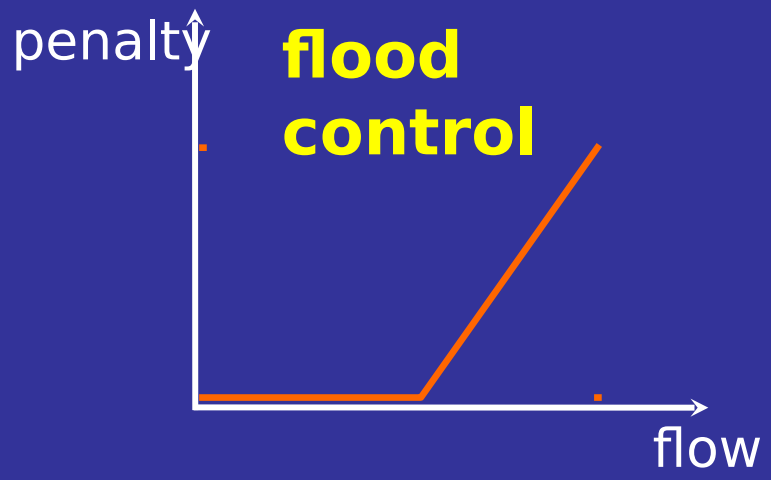
Use of Optimization AND Simulation

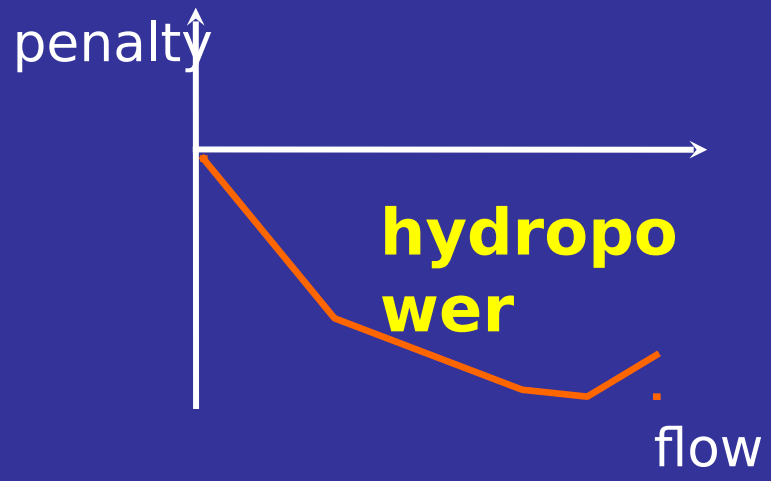
- Optimization and Simulation models play a complimentary role in developing operating rules
  - Optimization models make decisions that maximize benefit, but decisions can't be reproduced in real-time
    - STEP 2: Must infer operating rules that approach those optimal operations (determined with perfect foresight…)
  - Simulation models demonstrate the outcome of proposed rules, and allow adjustments to target the outcome achieved by the optimization

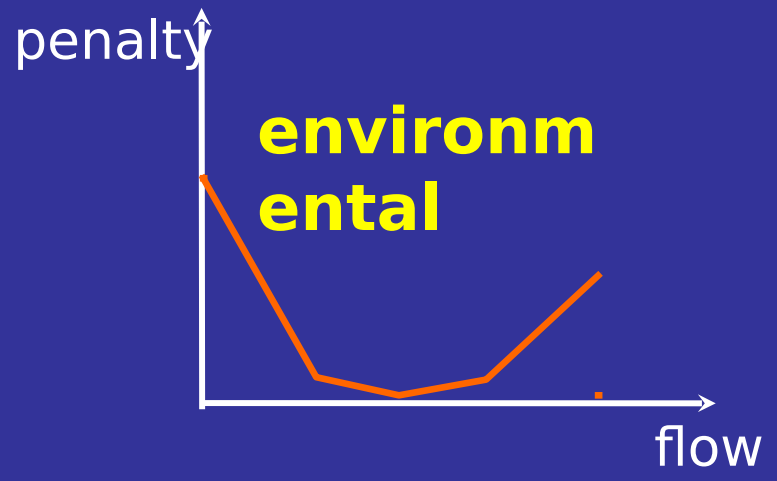
What Optimization Does

- Focused on maximizing the OBJECTIVES of system operations as defined by stakeholders
- No previously defined rules -- don't tell the system how to achieve the objectives
- Stakeholders and experts articulate system objectives by defining a series of penalty curves
  - this is how we tell the model what is good, and for whom

Examples of Penalty Curves







Mississippi Headwaters Study Area

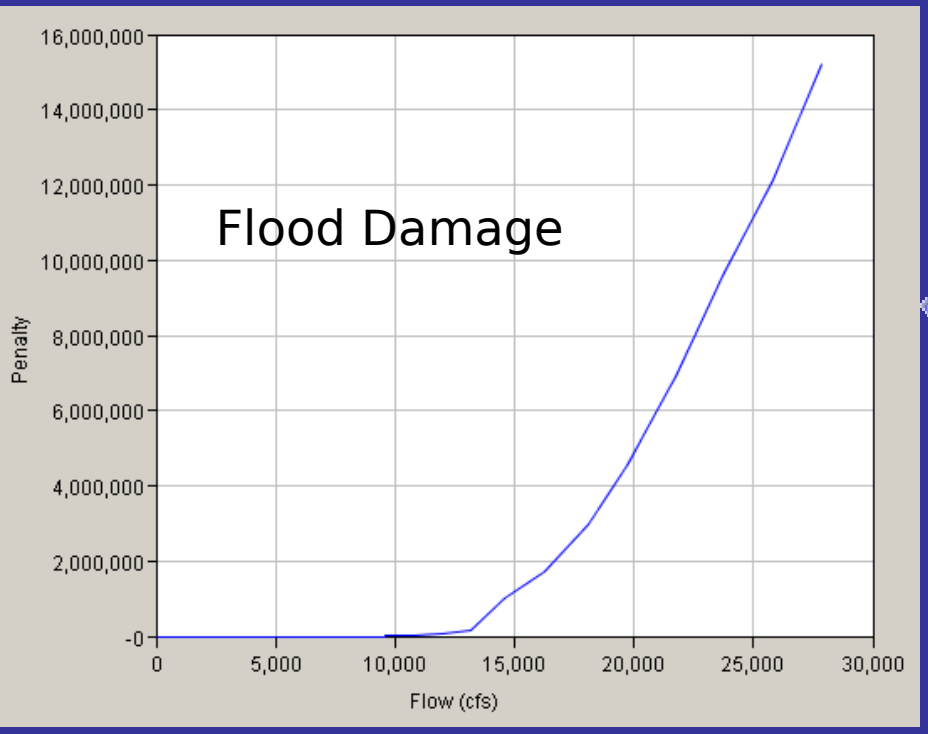
- ROPE (Reservoir Operating Plan Evaluation) Study
- Central Northern Minnesota
- 6 Corps Reservoirs
- 3 other Reservoirs
- Extends from Lake Bemidji to St. Paul

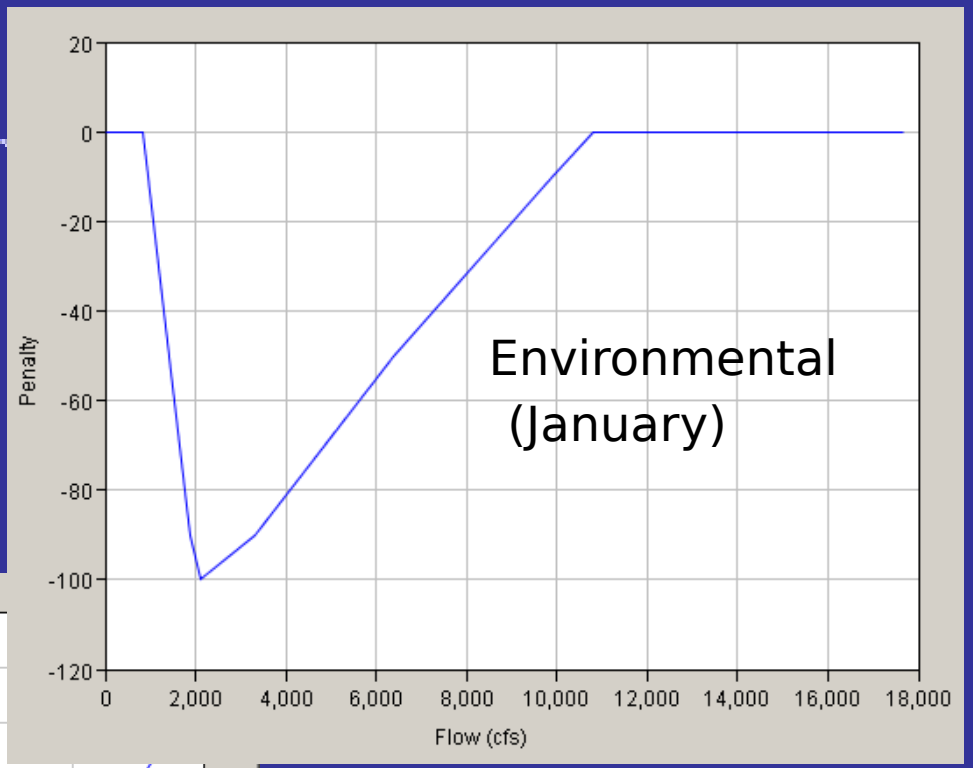
Summary of Objectives

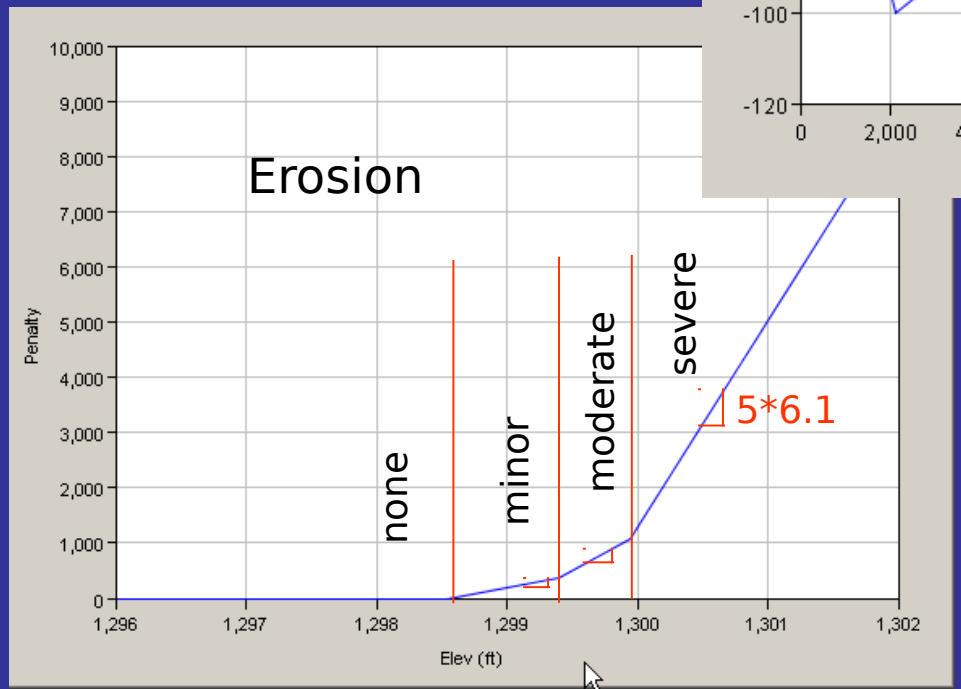
- Flood Protection ($damage and #structures)
- Recreation ($/day and %-of-maximum)
- Erosion
- Environmental
- Hydropower
- Water Supply and Waste Assimilation

Where do penalty curves come from?

- “Task Forces” use more detailed modeling to express how a given objective benefits or suffers from any level of flow or elevation
  - flood damage
    - hydraulic model that develops stage/flow relationship
    - structure inventory that relates stage to # structures affected and dollar damage
  - environmental
    - model that translates flow into suitable habitat measures
- What units? – penalty units are not important


Flood Damage
Penalty
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-0
0
5,000
10,000
15,000
20,000
25,000
30,000
Flow (cfs)

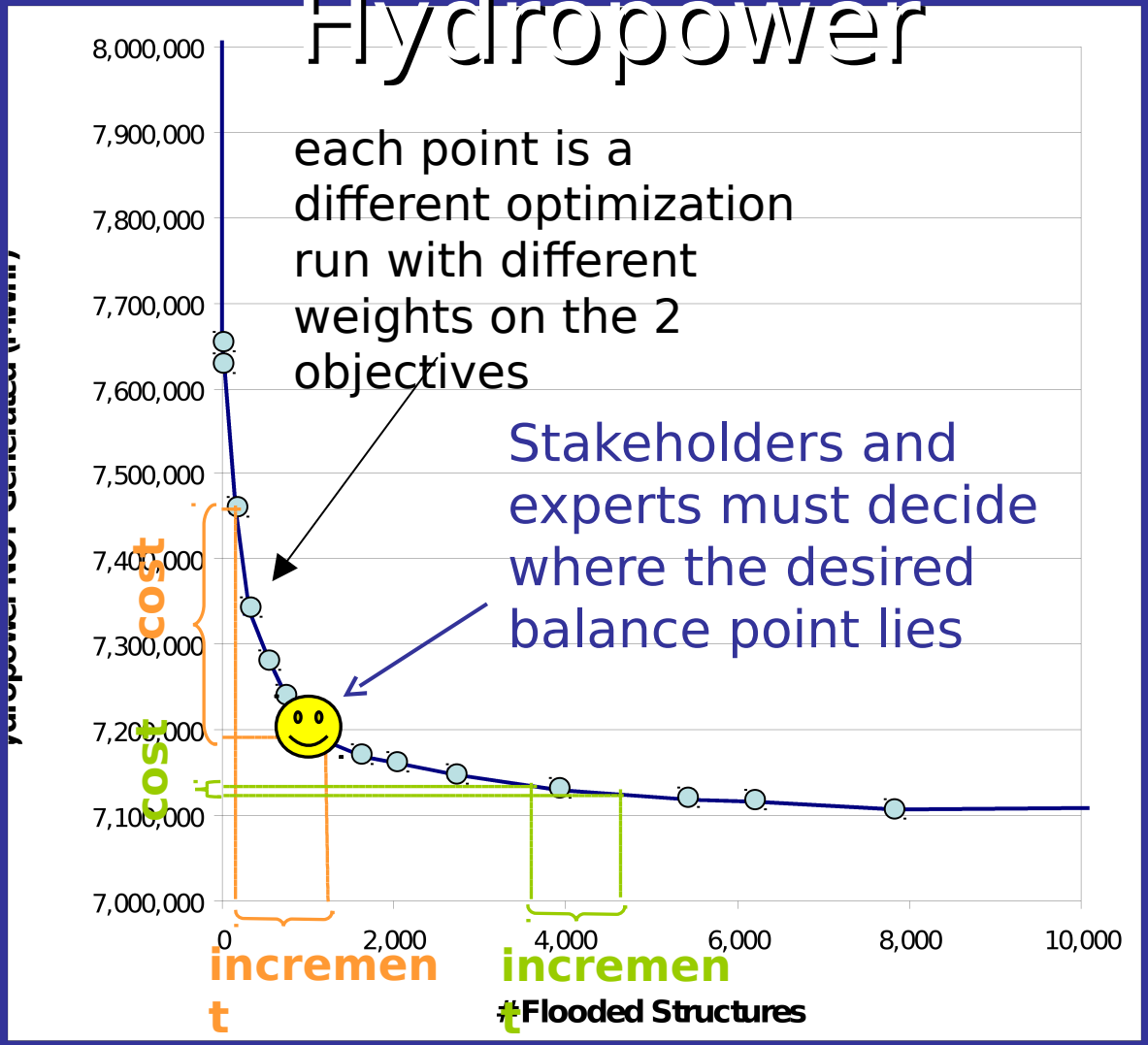

Environmental
(January)
Penalty
20
0
-20
-40
-60
-80
-100
-120
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
Flow (cfs)


Erosion
Penalty
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1,296
1,297
1,298
1,299
1,300
1,301
1,302
Elev (ft)
none
minor
moderate
severe
5*6.1

Differing Penalty Units

- Values and Penalties can be monetary
  - flood damage, price of water, hydropower
- Or, when value cannot be captured in dollars, any other unit that makes sense
  - environmental uses – acres of habitat, spawning area
  - recreation – user-days
- Can build a trade-off curve between 2 objectives with different penalty units
  - curve displays the loss to one caused by the gain to the other

Trade-off Curve between Flood Damage Reduction and Hydropower



HEC-ResPrm 2.0 - HeadWatersMiss_Mar06

File Edit View Optimization Alternative Reports Tools Help

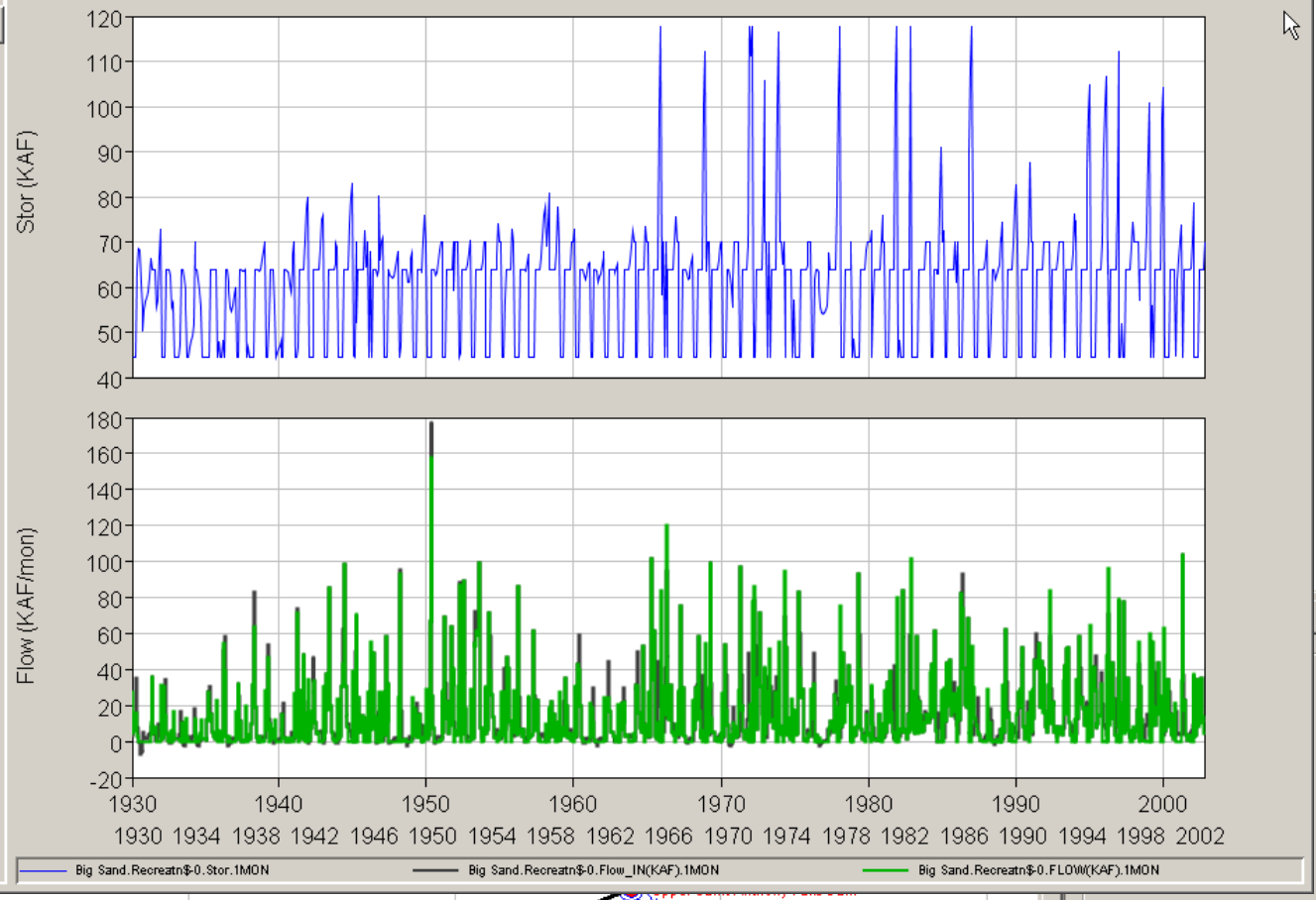
Module: Optimization

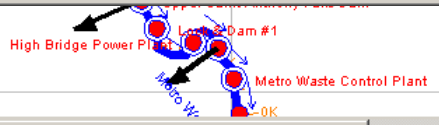
Optimization Control

Optimization:Jan 1930

default - 2:09PM

File Edit Plot View





Coordinates: 2053955 east, 353914 north

Local Workspace HeadWatersMiss_Mar06 opened

How do we use an optimization model?

- Run model for each objective individually
  - ensure results are consistent with goals
  - modify penalties if necessary

- Create trade-off curves for every 2 objectives
  - choose a set of weights that reflect the desired balance
- Run model for all objectives
  - using composite penalty functions with chosen weights
- Infer operating rules (look for patterns in output)
- Simulate operating rules to measure performance

Example: Penalties for Recreation

- One reasonable unit of measurement is reservoir usage in visitors per month
- If have some data on reservoir usage as a function of elevation, can use it directly
- Otherwise, perhaps relate usage to facilities available at any elevation...

Availability and Usage of Docks

Elev (ft)	Docks available
511	0 docks available
522	¼ docks available
528	¾ docks available
532	¼ docks available
540	0 docks available
545	

Additional usage unrelated to dock-availability

Season	Usage per ¼ of docks
Summer	600 visitors/month
Fall	200
Winter	20
Spring	350

Season	above docks	below docks
Summer	60	90
Fall	30	40
Winter	20	20
Spring	50	70

Usage as Function of Elevation

Elevation	Summer	Fall	Winter	Spring
	values in visitors per month			
511	60	30	20	50
522	600	200	20	350
528	1800	600	60	1050
532	1800	600	60	1050
540	600	200	20	350
545	90	40	20	70

Usage as Function of Elevation